NASA TT F-11,723

LIFE CYCLE AND RAPID CHANGING OF ZONE TIMES DURING AERIAL TRAVEL

J. LaVernhe

Translation of "Rythme de vie et changements rapides de fuseaux horaires au cours des voyages aeriens" from La Presse Medicale, Vol. 72, No. 44, pp. 2623-2626, October 24, 1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. August 1968

LIFE CYCLE AND RAPID CHANGING OF ZONE TIMES DURING AERIAL TRAVEL

/2623*

J. LaVernhe
Air France

ABSTRACT. Time displacement during air travel causes an interruption of the nychthemeral cycle, which in turn causes biological ill-effects. Commercial flying crews experience mainly fatigue and digestive disorders. The best ways for overcoming these two ill-effects are discussed.

Phileas Fogg, the famous hero of Jules Verne, having wagered his entire fortune that he would go around the world in eighty days, found himself faced with financial ruin on reaching London after a voyage of eighty days and five minutes! Had he lost his bet? No, because he had "gained a day" by traveling against the sun, and in reality he had an easy head start of twenty-three hours and fifty-five minutes. To be sure, his journal accounted for eighty-one elapsed days, but, during this time, London had lived through only eighty days - a miracle of the zone time and the international dateline change. In fact, our globe is divided by the meridians into twenty-four time zones, each covering fifteen degress of longitude, and the dateline change is located opposite London, in the middle of the Pacific Ocean.

Thus Phileas Fogg, traveling eastward, lived through the same day twice. Let us assume that he arrived on a Sunday, January 31, at 2400 hours in the neighborhood of the Samoan Islands; he would have to turn his calendar back immediately by one day and then read on his watch: Sunday, 0000 hours. Two consecutive Sundays would be recorded on the log book of the "Commandant:" Sunday, January 31, then Sunday, January 32, according to navy usage.

In our time, the four-engined line jets play havoc with zone times at every moment, penetrating right through them, and catching up with the sun or fleeing ahead of it, in defiance of the calendar.

Let us take the example of the regular Tokyo-Paris courier via Anchorage (Polar route), using a 707 Boeing.

---

* Numbers in the margin indicate pagination in the foreign text.

It is 2230 hours Sunday night in Tokyo when the "JET" takes off into the night. After flying two hours, the passengers see the sun rise and four and a half hours later the aircraft lands at Anchorage, where it is 1000, still Sunday morning, since the international date-line change has been crossed. At 1110, the craft becomes airborne again for another lap of nine hours which, after another night's flight, propels it to Hamburg at 7000, then to Orly at 9000 Monday morning.

We live in a strange era, where Father Time (Chronos), his eyes fixed on the slip stream of several 707 Boeings, has to look twice to note the time in turning over his hour glass. Furthermore, he is not the only one and his perplexity impinges on human mortals, whose physiological necessities have been governed by it for a long time. In effect, our life is strictly conditioned by the nychthemeral (day-night cycle), whether it is a question of the wake-sleep alternation or the digestive functions which themselves are dependent upon complex nemoendocrine activities. These circadian (from the Latin: circa diem [around the day]) cycles are not broken with impunity, and the commercial aviation crews flying long distance East-West or vice-versa **are daily finding that out.**

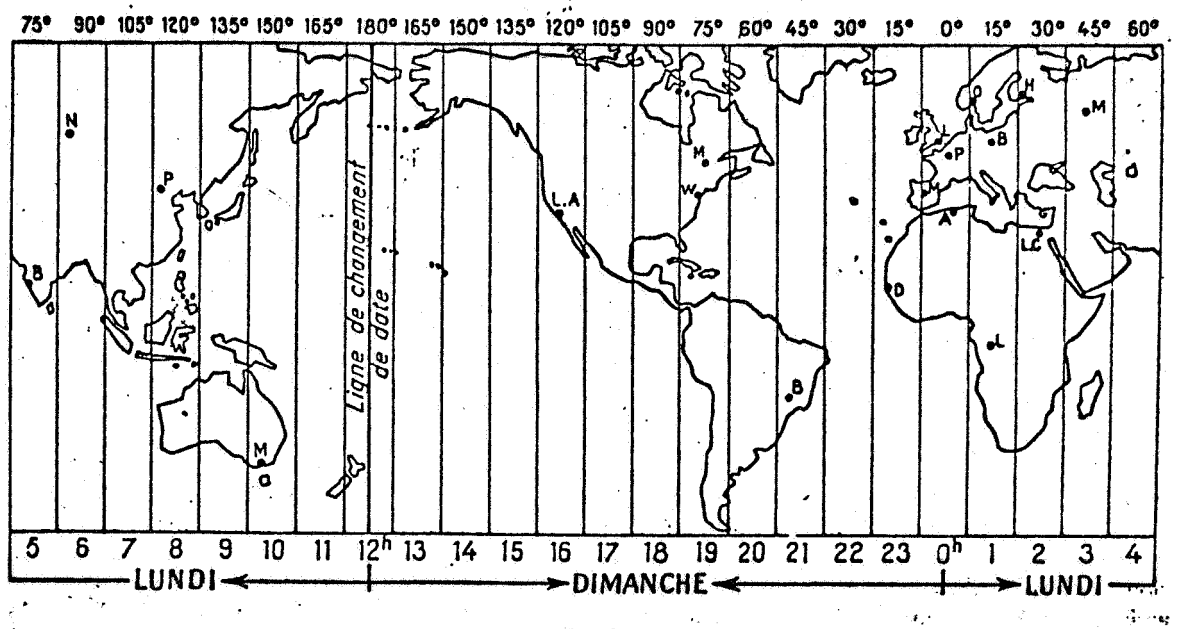
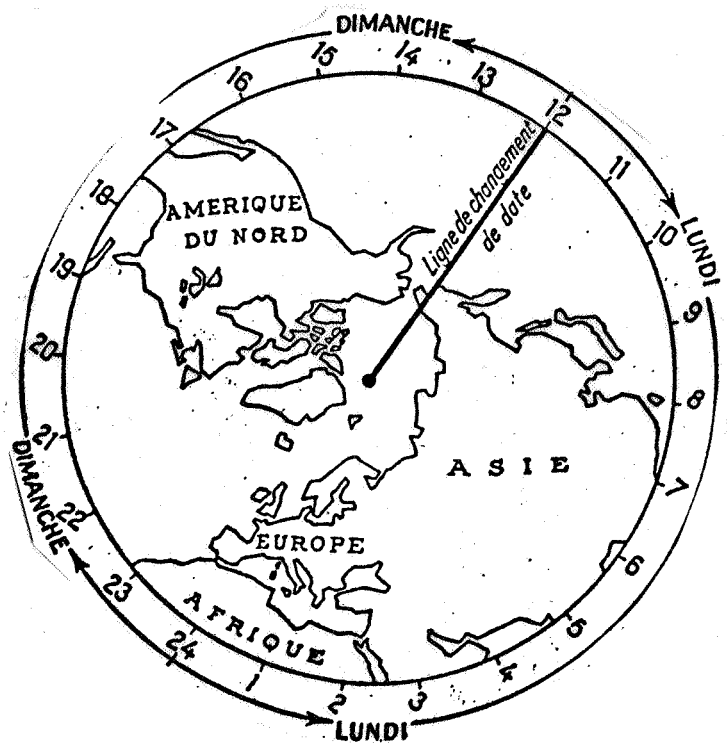


Fig. 1.

The zone in which the Greenwich meridian is located gives the hour of reference or "universal time" (U.T.). On both sides, each zone time change corresponds to a variation of one hour, ahead eastward, behind westward. If, on a map of the world, we place a pencil point over London at 0000 hours on Monday, we will find 0100 in Berlin, 0300 in Moscow, and so forth as far as Kamchatka, which is situated on the 180 meridian, opposite Greenwich. Under international convention, just



before crossing the "antimeridian," we are at 1200 hours on Monday and right after Sunday 1200 hours; in other words, we have reverted twenty-four hours backwards. That enables us, in completing the circuit of the world map, to find out point of departure again: Monday 0000 hours, at London. Crossing this "international date-line change" in the other direction, we would have passed from Sunday 1200 hours to Monday 1200 hours, by skipping a whole day. France, which should be on "universal time" (or Greenwich mean time) is in reality on "universal time" plus 1. Many countries have shifted the limits of the zone times to mould them on their frontiers.

I. The Nychthemeral Cycle /2624

The entire animal kingdom, beginning with a certain evolutionary state, is subject to a nychthemeral cycle, characteristic of each species. Day and night do not only determine the wake-sleep attention: they govern the cycle of the biological function also: breathing, circulation, digestion, heat regulation, neuroendocrine processes, etc. For a long time man has known the cyclical variation in the blood pressure, pulse, rectal temperature, in muscle tonicity, occular tonicity, urine volume, lachuymal and salivary secretions, etc. More recent are the measurements of the cellular nychthemeral cycles (mitotic activity of the digestive, nerve, sensory cells, etc.), the endocrine rhythms (excretion of the suprarinal hormones, thyroid activity for example), excretion of the electrolytes or of the blood coagulability.

It is possible to show these circadian cycles in animals, sometimes in an amusing manner. That is the case of Pieron's experiments with the glow worm. It is a known fact that the female of this insect (Lampyris noctiluen) turns on its phosphorescent light at night to draw the attention of the males. During the day, she economizes her reserves by extinguishing it. If she is placed in permanent darkness, she will continue to shine at night for a period of only four or five days. Beyond this period, the light will no longer extinguish itself, consequently,

there is an obvious effect of the nychthemeral cycle on the illumination of the glow worm.

Once installed, the biological cycle may sometimes break away from external cycles. This is shown in the experiments of Renner and Brown. After inducing some bees to come and look for their food at a fixed hour, Paris time, Renner noted that, when they were placed in New York, they retained the same habit, without taking into account the time displacement. Brown has experimented with oysters which he took from the New Haven oyster beds to transport them into a dark room at Evanston. He noted that these mollusks opened their valves completely for the first time at a light tide in New Haven. But, gradually, after a three week period, they brought the movements of their valves into line with the lunar rhythm at Evanston. Thus the lunation, too, is sometimes at the basis of biological cycles.

On the experimental pathology level, the study of the disturbances of the nychthemeral cycle is very interesting. Tcherkovitch has experimented with three monkeys, trained in ordinary conditioned, alimentary reflexes (light, ringing of bells). After a period in which the usual day-night cycle had been retained, the author reversed the sequence of stimuli in various ways. Each inversion took place while the preceding one had not yet been assimilated. Thus, the results were as follows: rest and obscurity by day, meal and wakefulness at night; two days and two nights of six hours each in the course of twenty-four hours; then the same cycle displaced six hours; however, the day taking the place of night; thereupon illumination for twenty-four hours, etc. At the end of two months of this type of aggression, all the monkeys had fits of neurosis. The conditioned reflexes were completely out of phase. One animal was very excited, another was prostated, and it took several months of normal regimen for recovery. One of the monkeys which was perfectly normal on leaving, died from an acute coronary sixty-four days after finishing the experiments.

In the field of aerospace medicine, Stronghold in the USA was one of the first to study these problems using US Air Force personnel. In France, Raboutet, Bousquet, Granoitier and Angiboust have published a paper on the effects of the time displacement on subjects examined at the Centre d'Expertises Medicales du Personnel Navigant de l'Aeronautique of Paris. The places were also concerned with the malfunctions which they experienced: Lodeesen, Flight Commander of a US Naval Aviation Company, collaborated with Crane, a doctor in the Federal Aviation Agency, in taking up the problem in a recent issue of a professional aviation periodical. Finally, the larger magazines periodically submit reports on the problem to their readers, thereby demonstrating its up-to-dateness and the interest taken in it by an even larger public.

II. Malfunctions of the Nychthemeral Cycle and Civil Aviation

Here are some examples of hourly displacements:

Paris	U.T. + 1 (*)	Anchorage	U.T. - 10
New York	U.T. - 5	Hong Kong	U.T. + 9
Tokyo	U.T. + 9	Los Angeles	U.T. - 8

(*) Universal time, i.e., Greenwich meridian time.

Among the physio-pathological malfunctions resulting from these displacements, the disturbances in sleeping are, subjectively, the most important. They consist of difficulties in going to sleep, or, per contra, nocturnal awakenings during which a real, temporary disorientation may be observed when the displacement amounts to nine or ten hours. As a matter of fact, when the local environment shows night time, "the internal physiological clock" still running according to life in France, shows noon. This discrepancy is the basis of the disorientation.

Digestive malfunctions follow immediately behind sleep disturbances in rank of importance. They are related to the displacements of meal times and bowel movements which upset the conditioned reflexes in digestion.

Let us take a few examples, from the regular routes of Air France:

A.F. 192

Displacement + 4	French time	Karachi time
Paris	1040	1440
Karachi	2050	0050

A.F. 003

Displacement - 9	French time	Karachi time
Paris	1315	0415
Los Angeles	0105	1505

At the time of the displacement eastward (Paris-Karachi = 4 hours displacement) the day speeds up. The passenger arrives at Karachi at 2050, Paris time, i.e., at the point designated to take his dinner after a ten-hour trip. But, alas! it is after midnight in Pakistan, all the restaurants are closed, and it is very difficult to get anything except a "snack" in his hotel room. Sleep is late in coming. To retire before 2200 hours French time (0200 local time) is rare. If one has to work upon arrival, he gets up after five hours of sleep. If the passenger has no appointment, he will try to sleep late, but will have difficulties with the hotel noises and daylight piercing the shuttles which are often inadequate, or even non-existent. And he will have to have his Monday meal at 0800! We can conclude that he is hardly fit. This West-East displacement is considered to be the most fatiguing.

The trip westward (Paris-Los Angeles = 9 hours displacement) entails an extension of the day. Arrival at Los Angeles takes place at 1605 local time after a 12-hour flight. It is the middle of the afternoon. If our passenger goes to bed on arriving, which his physiological clock, indicating 0100, will prompt him to do, he will wake up around 0800 by his clock, i.e., 2300 hours local time, with a long night of forced idleness in his room, and without any prospect of breakfast, which will not be served until eight hours later, the tea time of the afternoon! If one tries to adapt himself immediately to local time by dining or retiring early, it amounts to postponing sleep until about 0600, which is fatiguing, and generally does not prevent waking up in the middle of the local night.

These two examples point up a fatigue which may result from such aberration of the nychthemeral cycle. The occasional passenger takes it easily in stride; but for commercial crews making continuous round trips and accumulating sizable time displacements in various directions, the problem may become much more delicate. For example, it may happen /2625
that a flight over Tokyo (U.T. + 9) is followed by a flight over Los Angeles (U.T. - 8) after a 48 hour rest in Paris. In such a case, the time displacement may become one of the essential factors in aerial fatigue.

III. An Inquiry into the Objective Effects of Time Displacements on the Navigating Personnel in Commercial Aviation

The Medical Service of Air France has undertaken an investigation on the disturbances in the sleep and digestive processes of the company navigating personnel, making ocean flights over the North Atlantic. The questionnaire circulated was limited to this sector which has heavy traffic, and was aimed at obtaining identical experimental conditions and permitting one to group and compare the replies. We have scheduled

312 replies concerning the following flights, affected by a positive displacement of six hours.

Paris-New York and Paris-Montreal	{	Departure at the end of the local morning Arrival in the middle of the local afternoon Flight by day in approximately 8 hours
Montreal-Paris and New-York-Paris	{	Departure at the end of the local day Arrival at the beginning of the local morning Light by night in approximately 7 hours

The utilization of the data obtained has been made according to job classifications and age groups. The questionnaire was addressed as much to the 50 year old flight commander as to the 20 year old air hostess. Tables with statistics have been compiled and will be the object of detailed study in specialized aerospace medicine. To set them forth here would be tedious, consequently we shall merely retain the conclusions.

A. Paris-North America Flight

On arriving at New York or Montreal, 42% of the subjects have a tendency to sleep late, after 2100 local time, that is to say, American time; 23% adhere to French time by retiring early, before 1900 local time, and 35% go to bed at an intermediary hour (between 1900 and 2100 hours local time). The sleep acquired is often shorter than normal (55% of the cases) and less sound (29% of the cases). It is characterized as heavy, sluggish, sometimes fitful, broken by dreams or dozing and followed by a lassitude making rising painful. The fact of retiring late does not seem in any way to reduce sleep during this first night stop, since 72% of the replies indicate that waking up occurs at the normal French time, that is to say, between 0200 and 0500 local time. About 48% of the subjects succeed in going to sleep again and dozing more or less, with frequent awakening, until a normal time of rising. But for 24%, this waking up is final, and makes it impossible to fall asleep again. They fill the rest of the night reading or with personal work, while waiting for the possibility of eating breakfast. They hypnogenic drugs are widely used: 20% of the subjects use them during runs, as against 5% only in France: 44% of the hostesses consume them after flights: this is the most significant percentage, in relation to other job classifications. Most of the time, use of the medicine results from the impossibility of finding sleep because of fatigue and nervous tension; more rerely it is a question of going to sleep again during the night.

B. Layover on the American Continent

This layover varies in duration; it may last one night only or several nights; especially in the case where the crew makes a run on the American continent (New York-Mexico and round trip, for example)

before returning to France. As for the brief layover lasting only one night, a significant minority (3.4%) continues to live by French time. For layovers of at least two nights, the great majority (95%) adopts American time. During the American layover, 24% of the subjects evidence normal sleep from the first night, and 41% from the second nights. In 35% of the cases, 3 or more nights are required before recovering normal sleep. The personnel falling into the last category explain the reason for this difficult recovery as follows:

First night: more or less undisturbed sleep, heavy, resulting from fatigue, but only somewhat refreshing;

Second night: fatigue is no longer present to induce sleep and the time displacement is strongly felt causing waking up in the middle of the night;

Third night: the fatigue of the preceding two disturbed nights facilitates falling asleep, which then gives rise to a sufficient increment to local time to produce a waking up at a nearly normal hour.

Unusual digestive disturbances frequently occur in flight: dyseptic disorders (15% of subjects); diarrhea (9%), constipation (29%), which is particularly frequent among hostesses. During flight, 41% of the personnel experience digestive disorders. The following etiological factors are most often incriminated: displacement of meal times, unusual foods and condiments; impossibility of a bowel movement at the normal hour.

The ideal stopover time in America for crews on an ordinary round trip is a very controversial point. About 54% of the subjects request a rest of at least two nights; 46% perfer a layover of one night only. The arguments of the short stopover protagonists are as follows:

1 - a long stopover requires first of all an adaptation to American time and, on the return trip, a readaptation to French time, while a short stopover makes it possible to avoid the problems of displacement entirely.

2 - boosting rest periods in America is achieved at the cost of rest periods in France, which jeopardizes family life.

3 - relaxation taken in the normal framework is clearly more profitable than that taken during a stopover.

C. Return to France

Night flying is especially taxing: 62% of the subjects show drowziness during the flight and 52% drink coffee. In 3% of the cases (com-

mercial flight personnel) amphetamines are used. On arrival in Paris in the morning, 85% of the subjects sleep at best a few hours of the day. This sleep leads to the omission of a meal in 39% of the cases. The night following the return to France varies in quality, i.e., becoming worse as the layover in America gets larger. Sleep comes late (often 0200 or 0300) and the noises of the day are a frequent obstacle to the idle morning.

The time period to recover normal sleep is appraised differently. 28% of the subjects sleep normally from the first night, 42% from the second night and 25% from the third or subsequent nights.

The digestive disorders disappear in less than 24 hours in 60% of the cases.

*
* *

Summing up, a considerable portion of the flight personnel suffers more or less from changes in time zones, be it a matter of sleep (the most common), digestive functions or both. But it is certain that the time displacements are not the only ones responsible for malfunctions pointed out. Climatic variations, changes in nocturnal atmosphere (bed, noises, temperature, hygrometry, etc.) unusual diet, nervous tension, flying by night certainly play an important role.

A difference in the reactions and adaptation to time displacements appears among young subjects, who have not flown much, and old subjects with a wide experience in zone time changes:

- Between 20 and 30 years of age, 42% of the subjects retire late in New York, while those over 50 years, retire early.

The time difference exists in the preferred stopover duration in America:

Of those between 20 and 30 years of age, 67% of the personnel would like a stop of at least two nights. Above 50 years, 70% prefer a one night stop, which is more favorable to keeping French time.

- The subjects who retire early in New York and maintain French time completely are those who claim to sleep the best during flight and bounce back to French time most readily on the return trip.

The French regulation covering hours of flight and rest for crews /2626
does not take the time displacements into account. Ruffle-Smith has attempted to calculate the work of the navigation personnel by assigning a coefficient of equilibrium to gross hours flying time, taking into

account the number of landings and takeoffs, meteorological conditions, difficulty of work on board, etc. In our opinion, it would be appropriate to associate crossing of the zone limits with the factors appraising work in the air since it is clearly proved that a hitch on an East-West axis is fatiguing in a different manner than a technically similar hitch on a North-South axis.

IV. Conclusions

The importance of the nychthemeral biological cycle is revealed by animal experiments as well as by subjective malfunctions experienced by man when a break in these cycles occurs. While the physiopathological effects of time displacements could be neglected in the era of sailing ships, the extraordinary increase in the speed of crossing the zone times made possible by the airplane, lending a continuously more urgent up-to-dateness to the problem. At the present time, at 60° North latitude, i.e., on an axis running from Oslo to the southern coast of Alaska, a JET flowing westward at 850 km/h "turns" at the same speed as the earth: as far as it is concerned the sun remains stationary in the heaven. In a few years, the advent of the supersonic transport planes will even increase these displacements. The "Concorde" flying at Mach 2.2 i.e., at 2,500 km/h will link Paris with New York in about three hours (allowance made for landing operations, subsonic rises and descents): in one hour, two zone times will be traversed.

For flight personnel these speeds will furnish a neat solution to the problem of time displacements: round trips on the North Atlantic will become possible in the same day, with the same crew which, thus, will no longer be faced with any problem in keeping French time and will avoid flying by night. But if the Far East lines, for example, where flying times are long and stops frequent, must be serviced at Mach 2 or 3, the fatigue per kilometer for flight personnel will diminish, while the problem of time displacement will remain constant, since the rest stops will continue to prove to be indispensable to commercial exploitation of the airlines.

Usually the passenger does not cross a large number of zone times except intermittently. His difficulties are therefore more easily resolved. Nevertheless, it is a wise step, if one is employed in delicate business affairs requiring the full possession of his mental faculties to consider the time displacements and make provision for a difficult recovery time before talking business.

REFERENCES

1. Benitte, A.C. and Lefebvre-Desnoittes, R.: L'Inversion du rhthme cycthemeral. Ses consequences physio-pathologiques. Suggestions pour une recherche experimentale. Revue de Medecine aeronautique, Vol. 1, No. 1, pp. 59-69, 1961.
2. Dagorn, R.: Troubles du rythme de vie provoques par les vols a longue distance. Aviation, Industrie et Commerce, June 1964, pp. 1-6.
3. Fenno, R.M.: Aircrew conditioning for long range flight. Aerospace Medicine, Vol. 33, No. 4, pp. 447-452, 1962.
4. Flink, E.B. and Doe, R.P.: Effects of sudden time displacement by air-travel on synchronization of adrenal function. Proc. Soc. Exp. Biol. Med., Vol. 100, pp. 498-501, 1959.
5. Gatineau, A.: Fatigue du personnel navigant technique de l'aviation marchande. La Medecine Aeronautique, Vol. 11, No. 4, pp. 413-423, 1956.
6. Gerritzen, F.: The diurnal rhythm in water, Cl, Na and K excretion during a rapid displacement from east to west and vice-versa. Revue de Medecine aeronautique, Special No. 2, pp. 103-106, 1962.
7. Lodesen, M. and Crane, J.E.: Racing the sun. Airline pilot, Vol. 33, No. 1, p. 8, 1964.
8. Pieron, H.: Quelques reflexions et observations a propos de l'induction des rythmes chez les animaux. J. Psychol. Norm. Path., Vol. 34, pp. 397-412, 1937.
9. Raboutet, J., Bousquet, C., Granotier, E., and Angiboust, R.: Troubles du sommeil et du rythme de vie chez le personnel navigant effectuant des vols a longue distance. La Medicine Aeronautique, Vol. 13, No. 4, pp. 311-322, 1958.
10. Renner, M.: Ein Transozeanversuch zum zeitsinn der Honigbiene, Naturwiss, Vol. 42, pp. 540-541, 1955.
11. Ruffle-Smith, H.P.: An investigation of pilot's work load and working conditions in a civil airline. Flying personnel research committee report, No. F.P. RC/1190 to Air Ministry, London.
12. Strughold, H.: Physiological day-night cycle in global flights, J. Aviat. Med., Vol. 23, pp. 464-473, 1952; Physiologic day-night cycle after long distance flights. Inter. Record of Med. and general practice clinics, Vol. 168, pp. 576-579, 1955.
13. Tcherkovitch, G.M.: Production experimentale d'une nevrose chez le singe par modification du rythme nycthemeral. Bull. Biol. Exp. Med., 1959, Vol. 47, No. 8, pp. 21-24, 1959.

Translated by the Translation
and Interpretation Division
Institute of Modern Languages

MK/ag